


**CLEARWATER SHALE FORAMINIFERA**  
**ATHABASKA RIVER, ALBERTA**

**L.J.MARTIN**

**1954**

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## ABSTRACT

Study of a prolific calcareous foraminiferal fauna from the type section of the Lower Cretaceous Clearwater formation on the Athabaska River, Alberta, reveals forty six species and three varieties belonging to the genera Ammobaculites, Ammodiscus, Bathysiphon, Eggerella, Haplophragmoides, Leptodermella, Tritaxia, Verneuilina, Marginulina, Nodosaria, Patellina, Saracenaria, Sphaeroidina, Tristix, Vaginulina, and Valvulinaria. All but three of the above are described and figured. Thirty five species are new and eleven have been previously described from the correlative Loon River and Moosebar formations and from the Cummings member of the Mannville formation. The correlation of the Cummings member with the Clearwater formation is confirmed. The ecology of the fauna is shallow neritic in a normal marine epicontinental basin in a middle Albian transgressive flooding.





UNIVERSITY OF ALBERTA

CLEARWATER SHALE FORAMINIFERA  
FROM THE ATHABASKA RIVER, ALBERTA.

A Dissertation

Submitted to the School of Graduate Studies  
in partial fulfilment of the requirements for the  
degree of Master of Science.

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Department of Geology

by

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## CHAPTER 1

Introduction

A calcareous foraminiferal fauna discovered in outcrop sections of the Lower Cretaceous Clearwater formation of the Athabaska River was considered sufficiently outstanding to warrant a careful examination as most previously studied Western Canadian Lower Cretaceous microfaunas have included only rare<sup>1</sup> calcareous forms. This paper incorporates the description of this fauna and some stratigraphic observations on these Clearwater foraminifera.

Thirty two calcareous species of the fourteen genera Dentalina, Discorbis, Eponides, Globulina, Gyroidina, Lenticulina, Marginulina, Nodosaria, Patellina, Saracenaris, Sphaeroidina, Tristix, Vaginulina, and Valvulineria, and seventeen arenaceous species belonging to the eight genera Ammobaculites, Ammodiscus, Bathysiphon, Eggerella, Haplophragmoides, Leptodermella, Tritaxia and Verneuilina are described and figured. Several genera and some of the species are in common with the faunas of the Moosebar (Stelck, 1950) and Loon River (Wickenden, 1951) formations. Correlations are made with the Moosebar and Loon River shales on the basis of these similarities in fauna.

Two species, Ammobaculites humei Nauss and Haplophragmoides gigas minor<sup>Nauss</sup> are found in this fauna and the fauna from the Cummings member of the Mannville formation of





Lloydminster area, Alberta, and correlation of the Clearwater formation with the Cummings member is confirmed.

### Previous Work

Four foraminiferal suites have been described from formations in Alberta of a similar stratigraphic position. In an unpublished Stanford University Ph.D. thesis C.R. Stelck (1950) describes foraminifera from the Moosebar shale of upper Pine river, British Columbia. This latter suite contains numerous species but unfortunately contains relatively few calcareous forms. R.T.D. Wickenden (1951) has described a fauna from the Loon River formation, below Peace River town, Alberta, in the Peace valley. The figures are blue line drawings in a G. S. C. preliminary geological paper and lack certain detail for purposes of comparison. This latter suite, however, does contain several calcareous species, apparently with close affinities to forms of the Clearwater fauna.

F.H. Trollope (1951) has described a foraminiferal fauna from the Loon River formation of the lower Peace river area and several Clearwater species are found to be present in this suite. The foraminifera of the Mannville formation of the Lloydminster area, Alberta, have been described by A.W. Nauss (1947) and forms similar to Clearwater species are included in a fauna from the Cummings member of the Mannville formation.



Nature of Material and Method of Treatment.

The large number of specimens and their fine preservation reflects the care taken in the field to obtain clean fresh shale samples. The samples were collected by an interrupted interval method whereby samples are selected from a six inch stratal thickness at arbitrary footages determined in large measure by the nature of the outcropping beds. This method seems to yield better faunas in Western Canada outcrop than channelling which yields a higher percentage of weathered material and a lower faunal recovery. The samples were hand picked and placed in postal cotton bags and shipped to the University of Alberta.

At the University of Alberta geological laboratories the shale samples were placed in ordinary tap water in clean, tightly covered half pint jars and left to stand for one to three months. The contents were then washed through a series of screens of 16, 48, 80, 100 and 120 mesh to the inch arranged in progressively finer order. The portion of the sample which washed through the finest of the screens was collected in a pan, inspected for minute forms, and discarded. The residue on each of the screens was decanted onto a saucer, dried, and bottled.

It was found that the shale disintegrated readily, and in many cases directing a small stream of water onto the sample was sufficient to wash it completely, while in others a small amount of agitation with the fingers was necessary.



This ease of disintegration is probably in part responsible for the perfect preservation of many of the delicate calcareous tests.

The microfauna was picked from the washed samples by spreading the sample in a single layer on a black plastic plate ruled off with fine lines the width of the microscope field apart, and removing specimens with a moistened size 00 camels hair brush. The foraminifera and other organic micro-elements were mounted on ten cell micropaleontological slides with gum tragacanth.

Hypotypes were selected and mounted on single cell slides. Plates were made by photographing drawings of the hypotypes, retouching the photographs and rephotographing them on a black background.





## CHAPTER 2

### The Clearwater Formation

The Clearwater shale outcrops along the Athabaska river, Alberta, below Grand Rapids. These outcrops make up the type section. The Clearwater formation was first named by R.G. McConnell in 1893 when encountered in a reconnaissance survey of parts of Western Canada. The formation is composed of interbedded shales, silty shales and sandstones, entirely marine and approximately 275 feet thick in the type section.

The macrofauna found in this formation is variously designated as the Lemuroceras, Beudanticeras affine, or Inoceramus dowlingi fauna. It includes, besides the above, numerous other pelecypods and rare gastropods, among which are the following:

Nucula athabaskensis McLearn

Yoldia kissoumi McLearn

Inoceramus dowlingi McLearn

Entolium irenense McLearn

Pecten alcesianus McLearn

Camptonectes matonabbei McLearn

Brachydontes athabaskensis McLearn

Goniomya matonabbei McLearn

Psilomya peterpondi McLearn

Psilomya elongatissima McLearn

Arctica limpidiana McLearn



Protocardia alcesiana McLearn

Integricardium (Onestia) onestae (McLearn)

Tellina dowlingi McLearn

Turnus lacombi McLearn

The fauna places the age of the formation as earliest middle Albian in the Lower Cretaceous.

#### Correlatives of the Clearwater formation

A fairly well established correlation has been set up between the Clearwater formation of the Athabaska River and the Moosebar and Loon River formations of the upper and lower Peace river, on the basis of macrofauna. These correlations are further re-enforced by the few microfaunal studies which have been undertaken. The three formations do not appear, however, to be of exactly the same duration. A complete section of Loon River includes beds both above and below the Clearwater formation, while the Clearwater includes a basal portion that would lie beneath the Moosebar. These relationships are diagrammatically expressed in the correlation chart included in this chapter.

In subsurface studies Badgley (1952) correlates the Clearwater shale with the Cummings member of the Mannville formation as penetrated in drilling in the Lloydminster area of Alberta. Workman (1951) apparently correlates the Clearwater shale with both the Wilrich member and part of the Falher member of the Spirit River formation which is encount-



ered in drilling in the Peace River area. The formations set up in Workman's paper, however, are units used in electric-log correlation and are not readily applied to formation outcrops.

#### Micropaleontology and Correlation

The foraminifera were collected from nine samples of Clearwater shale and are considered as a single fauna although these samples cover 165 feet out of the middle of the Clearwater formation, a considerable thickness of strata. A large number of the species are undoubtedly new and some may not extend through the entire section. Rather than attempt the outlining at this time of a sequence of fine hemera whose definition would at present be meaningless as the samples are not continuously collected, it is thought best to treat these Clearwater microfossils in a purely descriptive manner. This gives future workers a practical foraminiferal biozone for correlative work.

This biozone may be recognized in part as the Clearwater fauna is suggestive in aspect of both the Moosebar and Loon River faunas.





CORRELATION OF LOWER CRETACEOUS FORMATIONS IN NORTH-CENTRAL ALBERTA & NORTHEASTERN B.C.

				UPPER PINE BC.	PEACE RIVER	PEACE RIVER WORKMAN	ATHABASKA	N.W. MANNVILLE I	FAUNAL ZONE	
LOWER CRETACEOUS	UPPER CRET.	LOWER CENOMANIAN	DUNVEGAN		DUNVEGAN	DUNVEGAN		LABICHE	LLOYDMINSTER	UNIO DOWLINGI ACANTHOCERAS NEOGASTROPLITES
	UPPER ALBIAN	F O R T   S T .   J O H N   G R O U P	CRUISER	SHAFTESBURY	SHAFTESBURY	PELICAN	VIKING			
			GOODRICH							
			HASLER							
	MIDDLE ALBIAN	F O R T   S T .   J O H N   G R O U P	COMMOTION	PEACE RIVER FORMATION	CADOTTE	PADDY	JOLI FOU	JOLI FOU	HAPLOPHRAGMOIDES GIGAS	
					HARMON	CADOTTE				
					"NOTIKWIN"	HARMON	GRAND RAPIDS	O' SULLIVAN		
					"MONIAS"	NOTIKWIN				
			MOOSEBAR	LOON RIVER	WILRICH	CLEARWATER	BORRADAILE			
							ISLAY			
	APTIAN APT. ALBIAN	BULLHEAD GROUP	BASAL SANDS	BLUESKY	MC MURRAY	DINA	INOCERAMUS DOWLINGI			
				BULLHEAD GROUP						





## CHAPTER 3

### Description of Species

The species described here were found in nine shale samples of the Clearwater formation. Thirty-five species and three varieties are new and not formally described in previous literature. Others are forms found by earlier workers in the Moosebar and Loon River formations, as indicated in the preceeding chapter.

Species described herein are figured on plates 1 and 2.

The classification used follows Cushman's generic descriptions, <sup>some</sup> are referred to some of the genera of Glaessner and Galloway.

### Foraminifera Species

Phylum Protozoa

Order Foraminifera

Family Rhizamminidae

Bathysiphon Z-7-56-A

(Plate 1, figures 3 & 4)

Test elongate, slightly tapering, straight; wall composed of fine grained quartz well cemented to smooth finish; ends of tube open.

Length of hypotype: 0.78 mm., maximum diameter: 0.14 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.



Remarks: The irregularity of the paratypes suggests that this should be reassigned to Hyperammina but no proloculus has been found to date.

Family Saccamminidae

Leptodermella Z-7-54-A

(Plate 1, figures 25, 26 & 33)

Test plano-convex, ovate in outline; wall composed of an inner chitinous layer covered with a thick layer of loosely cemented mud; aperture large, elongate, simple, occupying a large portion of the ventral face.

Maximum diameter of hypotype: 0.62 mm., minimum diameter: 0.42 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from L. Z-7-54-B in wall composition, size, and character of the aperture.

Leptodermella Z-7-54-B

(Plate 1, figures 20, 21 & 22)

Test plano-convex, oval in plan; dorsal side raised to low blunt point; wall composed of fine clear quartz grains with calcareous cement; aperture simple, in depression in centre of ventral side with supplementary opening on dorsal side just above rim and fine slit running across rim connecting the two.



Maximum diameter of hypotype: 0.36 mm., minimum diameter: 0.27 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from L. Z-7-54-A in being composed of sand grains, having a supplementary aperture, and in being smaller.

Family Ammodiscidae

Ammodiscus Z-7-54-A

(Plate 1, figures 9 & 10)

Test planispiral, evolute, with proloculus and long undivided second chamber; wall composed of fine clear quartz grains with large amount of calcareous cement; spiral suture slightly depressed; aperture simple, formed by the open end of second chamber, occasional small constrictions noted along second chamber.

Diameter of hypotype: 0.37 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Appears very similar to Wickenden's Ammodiscus species A from the Loon River and lower Peace River formations of the Peace river area, Alberta.





## Family Lituolidae

Ammobaculites humei Nauss

(Plate 1, figures 11 &amp; 12)

Ammobaculites humei Nauss 1947, Journal of Paleontology, 1947, Vol. 21 Plate 48, figure 1.

Test elongate, compressed; early portion of six or seven chambers close coiled followed by four or five chambers in rectilinear series; wall composed of clear, coarse, sub-angular quartz grains and little cement; sutures depressed; aperture terminal, simple.

Length of hypotype: 0.76 mm., width coiled portion: 0.26 mm., width unilinear portion: 0.22 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This is indentical to Ammobaculites humei Nauss 1947 from the Cummings member of the Mannville formation of the Lloydminster area, Alberta. It also appears very similar to Trollope's Ammobaculites 363-B from the upper part of the Loon River formation, Peace river area, Alberta, and to Wickenden's Ammobaculites species A from the same area.



Haplophragmoides gigas minor Nauss 1947

(Plate 1, figures 1 & 2)

Haplophragmoides gigas minor Nauss 1947, Journal of Paleontology, 1947, Vol. 21 Plate 49, figures 10a and 10b.

Test compressed, planispiral, involute, seven chambers in last whorl; chambers inflated giving distinctly lobate periphery; wall thin, composed of fine clear quartz grains with white calcareous cement smoothly finished to semi-porcelainous appearance; sutures depressed; aperture simple, at the base of the apertural face of last formed chamber.

Maximum diameter of hypotype: 0.39 mm., minimum diameter: 0.30 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from H. Z-7-56-B in size only and may be the mature form thereof. The species is identical to that figured by Nauss from the base of the Cummings member of the Mannville formation of the Lloydminster area, Alberta.

Haplophragmoides Z-7-56-A

(Plate 1, figures 29 & 30)

Test large, planispiral, involute; seven to nine



chambers in last whorl; sutures radial, flush to slightly depressed; umbilicus partially filled; wall thick, composed of angular clear quartz grains with a large amount of cement, cement lessening on final chamber; aperture simple, at base of apertural face of last formed chamber.

Maximum diameter of hypotype: 1.03 mm., minimum diameter: 0.89 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Haplophragmoides Z-7-56-B

(Plate 1, figures 31 & 32)

Test small, compressed, planispiral, involute; six to seven chambers in last whorl; sutures flush except periphery which is very slightly lobate; wall smooth, thin, composed of fine clear quartz grains with white calcareous cement giving a nearly porcelainous appearance; aperture a long slit at base of last chamber.

Maximum diameter of hypotype: 0.26 mm., minimum diameter: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.



Hypotype: University of Alberta type collections.

Remarks: Possibly an immature form of H. gigas minor Nauss as they differ only in size.

Haplophragmoides Z-5-3-C

(Plate 1, figures 18 & 19)

Test small, partially involute, robust, planispiral; chambers inflated sub-globular, seven in last whorl; sutures depressed; wall thick, composed of clear quartz grains and a small amount of cement, grain size large in proportion to the size of the test; aperture a low slit at base of last chamber.

Maximum diameter of hypotype: 0.19 mm., minimum diameter: 0.17 mm.

Hypotype locality: Type section Clearwater formation, station 1, below Grand Rapids, Athabaska river, Alberta, about 98 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Differs from H. Z-7-56-F in having larger sand grains, a thicker wall, and less cement. It is possibly the immature form of H. Z-5-D. Except for position of aperture this could well be the early coiled portion of Ammobaculites humei Nauss.

Haplophragmoides Z-5-D

(Plate 1, figures 27 & 28)

Test compressed, planispiral, involute, seven chambers in last whorl; umbilicus open; wall thin, composed of large







clear quartz grains, low in cement; sutures flush; aperture a low slit at base of last formed chamber; surface has slight glazed appearance.

Maximum diameter of hypotype: 0.60 mm., minimum diameter; 0.52 mm.

Hypotype locality; Type section Clearwater formation, station 1, below Grand Rapids, Athabaska river, Alberta, about 95 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from H. Z-7-56-G in having slightly larger sand grains and a thinner wall.

Haplophragmoides Z-7-56-F

(Plate 1, figures 5 & 6)

Test planispiral, involute, eight or nine chambers in last whorl; periphery rounded; sutures flush; wall thin, composed of fine clear quartz grains with large amount of calcareous cement; aperture simple, at base of apertural face of last formed chamber.

Maximum diameter of hypotype: 0.26 mm., minimum diameter: 0.23 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.



Remarks: This form is very similar to H. Z-7-56-A but is much smaller in size and has more chambers in the last whorl. It may be an immature form.

Haplophragmoides Z-7-54-G

(Plate 1, figures 7 & 8)

Test planispiral, involute, seven or eight chambers in last whorl; wall composed of coarse sand grains of various composition, mostly quartz, cemented together with a small amount of cement; sutures flush; aperture a low slit at base of the last formed chamber.

Maximum diameter of hypotype: 0.32 mm., minimum diameter: 0.30 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form is similar to H. Z-7-56-A but is composed of larger sand grains in proportion to the size of the test.

Family Verneuilinidae

Tritaxia Z-5-A

(Plate 1, figures 13 & 14)

Test elongate; triserial, of about fifteen chambers; chambers slightly inflated, especially in later stages;



sutures depressed; wall composed of very fine clear quartz grains with a large amount of cement, surface finished smoothly to more or less porcelainous texture; aperture terminal, simple, on short neck; color white.

Length of hypotype: 0.62 mm., diameter; 0.36mm.

Hypotype locality: Type section Clearwater formation, station 1, below Grand Rapids, Athabaska river, Alberta, about 95 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Verneuilina Z-7-56-C

(Plate 1, figures 23 & 24)

Test a trochoid spire rapidly expanding; four or five whorls of three chambers each; chambers sub-globular, ultimate chamber inflated; wall composed of clear sub-angular quartz grains varying in size proportionately to the size of the chamber, with small amount of cement; sutures slightly depressed; aperture a low arched slit at base of inner margin of last formed chamber; color white.

Length of hypotype: 0.37 mm., diameter: 0.26 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.



Remarks: This form differs from V. Z-7-56-D in having a lower spire and in that the sand grains vary in size with the chamber.

Verneuilina Z-7-56-D

(Plate 1, figures 15 & 16)

Test a high trochoid spire with six whorls of three chambers each; chambers sub-spherical; wall composed of fine clear quartz grains with a large amount of calcareous cement in all but the last two chambers; grain size consistent throughout; sutures depressed; aperture a low arched slit at the base of the inner margin of the last formed chamber.

Length of hypotype: 0.42 mm., diameter: 0.20 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from V. Z-7-56-C in having a much higher spire, a larger amount of cement, and consistent grain size. There is a suggestion of extra chambers in the earlier portion so that this form may better be referred to Eggerella.





## Family Valvulinidae

Eggerella Z-7-56-A

(Plate 1, figure 17)

Test an elongate, trochoid spire; four whorls of five chambers each, two of four chambers, and two of three chambers; chambers sub-globular in shape, expanding slowly; wall of fine clear quartz grains with a large amount of calcareous cement; sutures depressed; aperture a slit at base of the inner margin of the last chamber; color brown in earlier portion, becoming almost white in latest chambers.

Length of hypotype: 0.42 mm., diameter: 0.24 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Eggerella Z-7-56-B

(Not figured)

Test a trochoid spire of variable height; two or three whorls of five chambers each, one of four chambers, one of three; chambers sub-spherical, expanding fairly rapidly; wall of fine clear quartz grains with a large amount of calcareous cement; sutures depressed; aperture an arched slit at the base of the inner margin of the last chamber.

Length of hypotype: 0.23 mm., diameter: 0.19 mm.



Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from E. Z-7-56-A in having a much shorter spire and only one four chambered whorl. It is believed to be the immature form of E. Z-7-56-A

Family Lagenidae

Dentalina Z-7-24-A

(Plate 1, figures 36 & 37)

Test elongate; large proloculus and three subsequent chambers; twelve longitudinal costae run from posterior tip of shell to aperture, two bifurcating as they cross the final suture; sutures slightly depressed, thickened; aperture terminal, radiate, near one margin of test; test calcareous opaque to translucent, white.

Length of hypotype: 0.62 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 161 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Could be megalospheric stage of a Marginulina.



Dentalina Z-7-56-A

(Plate 2, figures 6 &amp; 7)

Test elongate, cylindrical, slightly curved, consisting of six chambers in serial arrangement; wall calcareous, smooth, finely and sparsely perforate; sutures slightly depressed; aperture terminal, radiate, composed of five deep slits, displaced slightly towards convex side of test and strongly projecting from the terminal face.

Length of hypotype: 0.90 mm., length ultimate chamber; 0.29 mm., maximum width; 0.18 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Dentalina Z-7-56-B

(Plate 2, figure 5)

This specimen is incomplete consisting of only ultimate chamber and a portion of the penultimate chamber. The chambers present are elongate, cylindrical, slightly inflated; wall smooth, finely and sparsely perforate; suture slightly depressed; aperture terminal, displaced slightly towards the convex side of the test, radiate with six slits.

Length of ultimate chamber: 0.32 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta,



about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: The portion of this specimen present resembles D. Z-7-56-A but apparently formed part of a somewhat larger test, and the final chamber has a greater length as compared to diameter.

Dentalina Z-7-56-C

(Not figured)

Test elongate, chambers sub-spherical, elongate in slightly varying proportion in direction of longitudinal axis; sutures deeply depressed and thickened; perforations sparse and fine; aperture terminal, radiate, with six slits, displaced slightly towards convex side of test, forming an extended mammillate protuberance on the distal end of the test.

Length of chamber: 0.25 mm., width: 0.17 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Only three incomplete specimens were found, two of two chambers each, none of which are ultimate or prolocula, and a third consisting of a single ultimate chamber. All appear to belong to the same species. No evidence of





curvature of the test was observed in the two bi-chambered specimens but the displacement of the aperture in the third specimen indicates that they belong to Dentalina.

Dentalina Z-7-54-D

(Not figured)

Two specimens, possibly the same or related species; sutures oblique; test elongate, rectilinear or nearly so; sutures indistinct, flush with surface; four chambers, aperture unknown.

Length: 0.55 mm., width: 0.18 mm.

Unfigured types, University of Alberta type collections.

Lenticulina Z-7-56-A

(Plate 2, figures 24 & 25)

Test planispiral, involute, early chambers about half covered by later ones; spherical proloculus with eleven subsequent chambers, seven or eight in last whorl; sutures much thickened to approximately half the length of the adjacent chamber; periphery and exterior walls much thickened; ultimate chamber inflated, with broad ventral lobe at distal end; aperture radiate with median slit slightly elongated, at peripheral angle; color orange.

Maximum diameter of hypotype: 1.09 mm., minimum diameter: 0.89 mm.



Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Some forms of this species are very similar to Wickenden's Lenticulina Plate 1A, figure 13 from the Loon River and lower Peace River formations.

This species varies considerably in size, and in the size and shape of the ultimate chamber, which may be long and inflated resulting in a high ratio of greater to lesser diameter and a consequent Lenticulina aspect, or of a size proportional to those of the preceding chambers giving a circular profile as in Robulus. Since there appears to be an almost complete gradation in the forms examined from one type to the other all specimens are referred to Lenticulina. Those which possess a Robulus aspect may be juvenile forms.

#### Marginulina Z-7-54-B

(Plate 2, figures 42 & 43)

Test sub-ovate in immature stages, elongate in adult; early portion closely coiled, later portion of two to five chambers in slightly arcuate uniserial arrangement; ten to twelve longitudinal costae run from posterior tip of test to just onto ultimate chamber, several bifurcating as they cross ultimate suture; costae are stronger on earlier



chambers; sutures in coiled portion distinct but flush, in uncoiled portion slightly thickened and depressed, with last suture distinctly so; ultimate chamber somewhat inflated; aperture terminal, radiate, at the end of a small protrusion near the peripheral edge.

Length of hypotype: 0.84 mm., diameter: 0.29 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form resembles Stelck's Marginulina 22-146B from the Moosebar formation of the western Peace river area, Alberta.

Marginulina Z-7-48-D

(Plate 2, figures 40 & 41)

Test elongate, cylindrical in uncoiled portion; early chambers close coiled, sutures distinct, flush with surface; four coiled chambers visible; uncoils rapidly into almost rectilinear arrangement of six chambers, sutures thickened, depressed, chambers slightly inflated; twelve or thirteen heavy longitudinal costae run from beginning of uncoiled portion nearly to aperture; aperture terminal, near centre of terminal face, radiate (?); perforations large and distinct.

Length of hypotype: 0.78 mm., width: 0.25 mm.





Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 181 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Marginulina Z-7-48-F

(Plate 1, figures 34 & 35)

Test elongate, slightly compressed in early portion, later taking on a rounded triangular cross-sectional shape; early portion tightly coiled, later uncoiling with three chambers in uncoiled portion; sutures distinct, very slightly depressed, oblique; last two chambers slightly inflated; about sixteen longitudinal costae, five of which are on ventral side and run from coiled portion onto base of apertural face, remainder running half way up penultimate chamber; aperture central, terminal, with five or six small short radial slits.

Length of hypotype: 0.44 mm., width: 0.21 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 181 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This is a form from a similar stratigraphic position to suites described from the Loon River and Moosebar formations but shows fewer uncoiled chambers and more ribs than any Loon River species and has more oblique sutures than any described from the Moosebar. It shows



more similarity to Cristellaria miilleri Reuss 1863 but differs in having shorter ribs on all but the ventral side, more oblique sutures, and a sub-triangular ultimate chamber.

Marginulina Z-7-48-L

(Plate 2, figures 44 & 45)

Test small, sub-ovate in outline, length being less than twice width; early portion close coiled, later uncoiling with three chambers in uncoiled portion; sutures in coiled portion flush with surface, in uncoiled portion distinct and slightly depressed; eleven or twelve longitudinal costae originating on coiled portion and extending well up onto terminal face; penultimate chamber slightly inflated, ultimate chamber distinctly so, especially on ventral side; proximal suture of penultimate chamber approximately perpendicular to axis of test, ultimate suture distinctly oblique, as terminal chamber overlaps penultimate chamber on concave side of test; wall calcareous, finely perforate; aperture radiate, terminal, near centre of terminal face.

Length of hypotype: 0.44 mm., width: 0.23 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 181 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Possibly an immature specimen of M. Z-7-48-D.



Nodosaria Z-7-54-A

(Plate 2, figures 8 &amp; 9)

Test small, robust, rapidly expanding; four chambers in rectilinear arrangement; first suture flush, second and third depressed; aperture terminal, central, radiate; chambers slightly overlapping, last two inflated; wall calcareous, very finely perforate.

Length of hypotype: 0.36 mm., diameter: 0.15 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Strong resemblance to Stelck's Nodosaria 20-51B of the Moosebar.

Nodosaria Z-7-54-B

(Plate 2, figures 36 &amp; 37)

Test elongate, consisting of a spherical proloculus broken off on hypotype, and six subsequent chambers in rectilinear arrangement; sutures depressed, last two considerably more so than earlier sutures; wall calcareous, finely and profusely perforate, about 18 pores to a chamber length; aperture terminal, central, radiate.

Length of hypotype: 0.86 mm., diameter: 0.25 mm.



Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: Very similar to N. Z-7-48-C but differs in having more chambers and more deeply depressed sutures. It may represent the microspheric form of N. Z-7-48-C.

Nodosaria Z-7-48-C

(Plate 2, figures 34 & 35)

Test elongate, consisting of a sub-spherical proloculus and four subsequent inflated chambers; third chamber of hypotype smallest of five; sutures well depressed; wall finely and profusely perforate; aperture terminal, central, radiate.

Length of hypotype: 0.71 mm., diameter: 0.21 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form is similar to N. Z-7-54-B but proloculus is larger in N. Z-7-54-C and subsequent chambers do not expand as rapidly, so may represent the megalospheric stage of the latter.





Saracenaria Z-7-56-B

(Plate 2, figures 3 &amp; 4)

Test tending to be elongate; four chambers present, probably five in complete specimen where ultimate chamber is present; chambers wedge-shaped, slightly sigmoid; proloculus elongate, ellipsoidal; aperture terminal, at junction of periphery and terminal face, penultimate chamber with remnants of a radiate pattern; wall clear, calcareous, finely perforate, light yellow in color.

Length of hypotype: 0.29 mm., width: 0.21 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This specimen is incomplete apparently with only ultimate chamber missing. It differs from S. Z-7-56-G var. A in having a greater thickness and becoming uncoiled.

Saracenaria ? Z-7-56-C

(Plate 2, figures 20 &amp; 21)

Test large, elongate; narrowly triangular in cross-section; this is an incomplete specimen lacking the coiled portion; chambers in straight portion inflated, expanding slowly; sutures distinct, depressed, running from the inner edge obliquely, in sigmoid fashion to bend sharply near the



periphery until perpendicular to axis of test; aperture terminal, radiate, sub-central.

Length of last two chambers: 0.44 mm., width: 0.37 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This is apparently a transitional form tending towards a frondricularian pattern.

Saracenaria Z-7-56-G variety A.

(Plate 2, figures 12 & 13)

Test curvilinear, plano-convex in outline, flat margin made up of terminal face and first two chambers; five to seven chambers somewhat triangular in section; periphery sharply rounded; sutures distinct, slightly thickened, flush with surface; aperture terminal, radiate, at peripheral angle; wall calcareous, finely perforate with slight yellow color.

Length of hypotype: 0.32 mm., width: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This variety differs from varieties J and M of S. Z-7-56-G in having more slowly expanding chambers and a less inflated ultimate chamber.



Saracenaria Z-7-56-G variety J.

(Plate 2, figures 16 & 17)

Test moderately elongate, triangular in section; composed of large proloculus and five chambers in slowly expanding curved series, coiled about 160 degrees; chambers wedge-shaped, sharply rounded; terminal face flattened slightly, inflated proximally; sutures flush, distinct; aperture terminal, radiate with twelve to fourteen radiae; wall clear calcareous, finely perforate, light yellow in color.

Length of hypotype: 0.45 mm., width: 0.25 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from varieties A and M of **S.** Z-7-56-G in being much thicker at the ventral margin in proportion to the size of the test and more elongate.

Saracenaria Z-7-56-G variety M.

(Plate 2, figures 14 & 15)

Test ovate in outline, robust, all chambers slightly inflated; made up of five chambers, all large and distinct, expanding quite rapidly, with rounded triangular cross-section, rounded periphery; sutures distinct, thickened, depressed, aperture terminal, radiate, small, wall clear





calcareous, finely perforate, slight yellow color.

Length of hypotype: 0.28 mm., width: 0.17 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form differs from S. Z-7-56-G var. A in having more rounded and inflated chambers and in being more tightly coiled, and from S. Z-7-56-G var. J in being more robust, having a more rounded cross section, and less rapidly expanding chambers.

Saracenaria Z-7-56-H

(Plate 2, figures 22 & 23)

Test triangular ovoid; periphery sharply rounded, convex; inner margin slightly sigmoid; long dimension of early chambers at right angles to terminal face of test; six chambers, triangular in section, last three making up approximately ninety per cent of test; sutures distinct, later ones slightly impressed; aperture terminal, radiate; wall clear, calcareous, finely perforate, slightly yellowish.

Length of hypotype: 0.32 mm., width: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.



Remarks: This species differs from S. Z-7-56-G in being coiled only ninety degrees rather than nearly one hundred and eighty, and in having more elongate chambers and outline.

Saracenaria Z-7-54-L

(Plate 2, figures 18 & 19)

Test large, coiled approximately one hundred and eighty degrees; made up of a large proloculus and seven arcuate chambers, all slightly inflated; terminal face slightly inflated; sutures slightly depressed and thickened; aperture terminal at the peripheral margin; wall clear calcareous, finely perforate, slightly yellow.

Length of hypotype: 0.60 mm., width: 0.34 mm.

Hypotype locality: Type section Clearwater formation, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form resembles S. Z-7-56-G but is much larger and has more chambers, with a fully uncoiled portion. The ultimate chamber is missing so that the character of the aperture is obscure. It also could be a mature specimen of Saracenaria Z-7-56-G var. J.



Tristix Z-7-54-A

(Plate 2, figures 1 &amp; 2)

Test triangular in section with the sides markedly concave leaving little internal space within the test; spherical proloculus with about six subsequent chambers in curvilinear series; sutures in early portion depressed at angles of test, in later portion flush, indistinct; aperture terminal, radiate, at peripheral angle of test; shell calcareous, translucent, yellowish.

Length of hypotype: 0.36 mm., diameter: 0.29 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Vaginulina Z-7-54-A

(Plate 2, figures 38 &amp; 39)

Test elongate, compressed, consisting of eight elongate, flask shaped chambers; ventral margin smooth, rectilinear from anterior end of second chamber to aperture; other edge arcuate, somewhat olbulate, depressed at sutures; sutures distinct, depressed except at ventral margin; wall calcareous, finely perforate with somewhat larger perforations arranged in a single line along the anterior margin of each chamber; aperture terminal, radiate, at the end of a phialine expansion at the end of a long neck extending from the ventral margin.



Length of hypotype: 0.89 mm., width: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Family Polymorphinidae

Globulina Z-7-56-A

(Plate 2, figures 26 & 27)

Test ovoid globular; consists of one to five chambers; sutures flush, indistinct; wall smooth, very finely perforate; aperture terminal, radiate with a large number of fine radiae and small apertural chamberlet.

Length of hypotype: 0.26 mm., diameter: 0.16 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This species represents an extreme example of polymorphism. Some specimens have four or five chambers while others indential in size, shape, and external appearance are single chambered. This is a particularly good example of the tendency of individuals belonging to the family Polymorphinidae to completely subordinate the shape of chambers to external morphology.





The species is apparently identical to Wickenden's Globulina species Plate 1A figure 27 from the Loon River and lower Peace River formations of Peace river area, Alberta.

Globulina Z-7-56-B

(Plate 2, figures 10 & 11)

Test ovoid; sutures obscure; wall smooth, finely perforate; aperture large, radiate, with numerous long fine radiae (about 25) that become distally indistinct from alignment of perforations.

Length of hypotype: 0.62 mm., diameter: 0.36 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This specimen is partially crushed and the sutures are obscured but the suggestion is that the chamber arrangement is similar to that shown for Globulina Z-7-56-A. It differs from Globulina Z-7-56-A in being considerably larger in size and in having a larger aperture.

Family Rotaliidae

Discorbis Z-7-56-A

(Plate 1, figures 44, 45 & 46)

Test compressed, trochoid in a left hand spire; consists of a spherical proloculus and eleven subsequent chambers,



four in last whorl; dorsally convex, ventrally slightly concave in central area; chambers somewhat inflated ventrally; wall smooth, hyaline; sutures slightly depressed; aperture a slit at anterior ventral margin of last chamber.

Maximum diameter of hypotype: 0.23 mm., minimum diameter: 0.20 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This species resembles D. Z-7-56-B but has fewer chambers per whorl and has a left hand spire.

Discorbis Z-7-54-B

(Plate 1, figures 41, 42 & 43)

Test trochoid, compressed, consisting of three whorls with seven chambers in last whorl, increasing regularly in size; dorsally convex, ventrally nearly flat; periphery rounded; sutures flush, highly oblique on dorsal side; aperture a slit at anterior ventral margin of last chamber.

Maximum diameter of hypotype: 0.32 mm., minimum diameter: 0.29 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.



Remarks: Differs from D. Z-7-56-A in having several more chambers per whorl, more whorls and a right hand spire.

Eponides Z-7-54-A

(Plate 1, figures 47, 48 & 49)

Test trochoid, of two to three whorls of three chambers each; chambers inflated; sutures depressed; all chambers visible from dorsal side, only those of last whorl from ventral side; ventral umbilical area with a distinct solid mass; aperture a narrow opening extending one third of way up apertural face at an angle of about forty-five degrees to axis of coiling; wall calcareous, coarsely perforate; color light yellow.

Maximum diameter of hypotype: 0.21 mm., minimum diameter: 0.18 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Gyroidina Z-7-56-A

(Plate 1, figures 38, 39 & 40)

Test trochoid, all chambers visible from the dorsal side, only last whorl from ventral side; ventrally highly convex,





slightly umbilicate, dorsally slightly convex; test consists of a spherical proloculus and ten subsequent chambers expanding regularly, six or seven in last whorl; sutures distinct, slightly thickened, flush; spiral suture slightly depressed; aperture a low slit at base of apertural face on ventral side near umbilicus.

Maximum diameter of hypotype: 0.25 mm., minimum diameter: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: The umbilicus of forms of this species is so slightly umbilicate that these forms might possibly be referred to some other genus. The species may be split in two upon further study as some of the smaller forms have slightly inflated chambers. Cf. Wickenden Gyroidina species A, Plate 1A figure 30 from the Loon River and lower Peace River formations of Peace river area, Alberta.

Gyroidina Z-7-56-A variety B (sinister)

(Not figured)

Test trochoid in a left hand spire, all chambers visible from dorsal side, last whorl only from ventral side; ventrally highly convex, slightly umbilicate, dorsally slightly convex,



test consists of a spherical proloculus and about ten subsequent chambers six in last whorl; sutures distinct, flush; spiral suture slightly depressed; aperture ventral, a low slit at base of apertural face; color yellow.

Maximum diameter of hypotype: 0.22mm., minimum diameter: 0.19 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This form is nearly identical to G. Z-7-56-A but has a left hand spire. It is apparently identical to Trollope's G. 355-A from the upper part of the Loon River shale of Peace River area, Alberta.

#### Patellina Z-7-56-A

(Plate 2, figures 28, 29 & 30)

Test a low trochoid spire, biconvex; consists of a spherical proloculus and undivided second chamber of two whorls, followed by three to four whorls of two chambers per whorl; internally ornamented by small radial partial septa on dorsal wall; sutures flush on dorsal side, depressed on ventral side; inner edge of ventral side of chamber divided into three inflated lobes, the centre one offset so that the larger space between lobes contains the aperture while a platform extends from between the centre and posterior



lobes to cover the aperture of the previous chamber; wall finely perforate on dorsal side only; aperture a slit at base of inner margin of last chamber.

Maximum diameter of hypotype: 0.24 mm., minimum diameter: 0.22 mm.

Hypotype locality: Type section Clearwater formation, below Grand Rapids, Athabaska river, Alberta, about 189 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Valvulineria Z-7-54-C

(Plate 2, figures 46, 47 & 48)

Test circular in plan, biconvex; ventrally completely involute, dorsally nearly so; three chambers in final whorl, all of which are somewhat inflated; ventrally umbilicate; sutures depressed; periphery rounded; aperture a small slit at anterior ventral margin of last chamber near umbilicus.

Maximum diameter of hypotype: 0.22 mm., minimum diameter: 0.20 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: See Glaessner's generic description, to which this form is referred much more readily than to Cushman's. This form seems to have some relationship to Sphaeroidina and



Eponides. The similarity of wall structure, texture, and the arrangement of the ultimate three chambers leads us to believe that this is a fine example of foraminiferal polymorphism with the attendant adjustment of generic nomenclature.

This form resembles Wickenden's Allomorphina species B from the Loon River and lower Peace River formations of Peace river area, Alberta.

Family Chilostomellidae

Sphaeroidina Z-7-54-A

(Plate 2, figures 31, 32 & 33)

Test sub-spherical in outline; five chambers visible from exterior, all strongly and irregularly embracing; hemispherical in shape; wall coarsely perforate; aperture a rounded opening at margin of last chamber; color yellow.

Length of hypotype: 0.21 mm., width: 0.14 mm.

Hypotype locality: Type section Clearwater formation, station 2, below Grand Rapids, Athabaska river, Alberta, about 187 feet below the top of the Clearwater formation.

Hypotype: University of Alberta type collections.

Remarks: This could quite well be the megalospheric stage of Eponides Z-7-54-A as it occurs in the same suite and is similar in general appearance.





## Chapter Four

### Paleoecology

The Clearwater shale was deposited in a broad shallow epicontinental basin by a transgressive sea which swept down from the north in late lower Cretaceous time. Presumably deposition took place at a moderate rate as at no time was the water overly muddy, as is sometimes the case in basins where shale is being deposited, on a more rapidly subsiding sea floor. The microfauna present shows no indication of restriction by abnormal water conditions such as those found in lagoonal, littoral, or estuarine environments. *Ammonites* indicate open seaway connections.

Comparison with ecology of present day Gulf of Mexico foraminifera as determined by Phleger and Parker (1951) results in a fairly accurate picture of the depth of water in which the Clearwater fauna lived. Although all the forms of the genera common to both suites do not agree, the majority fall in a single range, viz: between 100 and 200 feet. The Clearwater calcareous genera agree particularly well indicating this bathymetric range. Most of the arenaceous genera may exist over a wide depth range and comparison gives rather inconclusive results.

The following is a list of genera common to those of the Clearwater suite herein described and to the suites of Phleger and Parker with the depth range, as determined by them.



<u>Genus</u>	<u>Depth Range</u>
<u>Ammobaculites</u>	Less than 50 m., sporadic to 200 m.
<u>Dentalina</u>	30 to 220 m.
<u>Discorbis</u>	45 to 200 m.
<u>Eggerella</u>	600 to 1900 m.
<u>Eponides</u>	65 to 3500 m.
<u>Gyroidina</u>	200 to 1850 m.
<u>Haplophragmoides</u>	85 to 3500 m.
<u>Lenticulina</u>	45 to 100 m.
<u>Marginulina</u>	30 to 160 m.
<u>Nodosaria</u>	45 to 3400 m.
<u>Valvulineria</u>	120 to 1150 m.

Although this list shows that most of the genera are found over a wide range of depths, it is notable that almost all may be found in water less than 85 meters in depth and none in less than 30 meters and a dominant number are found between 30 and 65 meters.



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## Explanation of Plates

### Plate 1

- Figs. 1 & 2, Haplophragmoides gigas minor Nauss X62. Fig. 1, side view, fig. 2, apertural view.
- Figs. 3 & 4, Bathysiphon Z-7-56-A, n.sp. X37. Fig. 3, side view, fig. 4, end view.
- Figs. 5 & 6 Haplophragmoides Z- 7-56-F, n.sp. X50. Fig. 5, side view, fig. 6, apertural view.
- Figs. 7 & 8 Haplophragmoides Z-7-56-G, n.sp. X42. Fig. 7, apertural view, fig. 8, side view.
- Figs. 9 & 10, Ammodiscus Z-7-54-A, n.sp. X49. Fig. 9, apertural view, fig. 10, side view.
- Figs. 11 & 12, Ammobaculites humei Nauss X46. Fig. 11, side view, fig. 12, apertural view.
- Figs. 13 & 14, Tritaxia Z-5-A, n.sp. X39. Fig. 13, side view fig. 14, apertural view.
- Figs. 15 & 16, Verneuilina Z-7-56-D, n.sp. X67. Fig. 15, side view, fig. 16, apertural view.
- Fig. 17, Eggerella Z-7-56-B, n.sp. X55, side view.
- Figs. 18 & 19, Haplophragmoides Z-5-3-C, n.sp. X53. Fig. 18, side view, fig. 19, apertural view.
- Figs. 20, 21 & 22, Leptodermella Z-7-54-B, n.sp. X42. Fig. 20, apertural view, fig. 21, dorsal view, fig. 22, side view.



- Figs. 23 & 24, Verneuilina Z-7-56-C, n.sp. X43. Fig. 23,  
side view, fig. 24, apertural view.
- Figs. 25, 26 & 33, Leptodermella Z-7-54-A, n.sp. X31. Fig. 25,  
apertural view, fig. 26, side view, fig. 33,  
dorsal view.
- Figs. 27 & 28, Haplophragmoides Z-5-D, n.sp. X47. Fig. 27,  
side view, fig. 28, apertural view.
- Figs. 29 & 30, Haplophragmoides Z-7-56-A, n.sp. X32. Fig. 29,  
side view, fig. 30, apertural view.
- Figs. 31 & 32, Haplophragmoides Z-7-56-B, n.sp. X46. Fig. 31,  
apertural view, fig. 32, side view.
- Figs. 34 & 35, Marginulina Z-7-48-F, n.sp. X66. Fig. 34,  
side view, fig. 35, apertural view.
- Figs. 36 & 37, Dentalina Z-7-24-A, n.sp. X52. Fig. 36, side  
view, fig. 37, apertural view.
- Figs. 38, 39 & 40, Gyroidina Z-7-56-A, n.sp. X60. Fig. 38,  
dorsal view, fig. 39, ventral view, fig. 40,  
side view.
- Figs. 41, 42 & 43, Discorbis Z-7-54-B, n.sp. X46. Fig. 41,  
ventral view, fig. 42, dorsal view, fig. 43,  
side view.
- Figs. 44, 45 & 46, Discorbis Z-7-56-A, n.sp. X74. Fig. 44,  
ventral view, fig. 45, dorsal view, fig. 46,  
side view.



Figs. 47, 48 & 49, Eponides Z-7-54-A, n.sp. X62. Fig. 47,  
side view, fig. 48, ventral view, fig. 49,  
dorsal view.





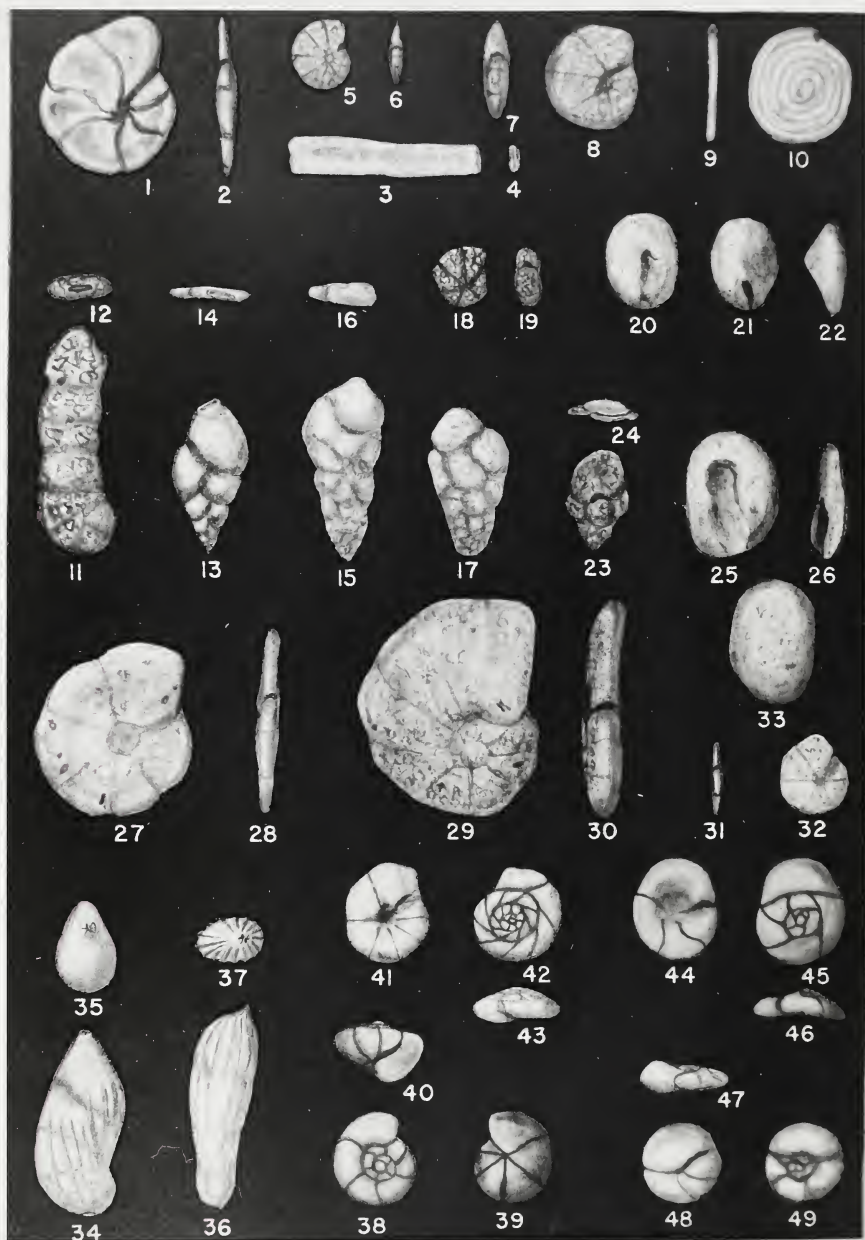


Plate I.



Plate 2

- Figs. 1 & 2, Tristix Z-7-54-A, n.sp. X64. Fig. 1, side view,  
fig. 2, apertural view.
- Figs. 3 & 4, Saracenaria Z-7-54-B, n.sp. X52. Fig. 3, side  
view, fig. 4, apertural view.
- Fig. 5, Dentalina Z-7-56-B, n.sp. X44, side view.
- Figs. 6 & 7, Dentalina Z-7-56-A, n.sp. X42. Fig. 6, side view,  
fig. 7, apertural view.
- Figs. 8 & 9, Nodosaria Z-7-54-A, n.sp. X50. Fig. 8, side  
view, fig. 9, apertural view.
- Figs. 10 & 11, Globulina Z-7-56-B, n.sp. X44. Fig. 10,  
apertural view, fig. 11, side view.
- Figs. 12 & 13, Saracenaria Z-7-56-G var. A, n.sp. X59. Fig. 12,  
side view, fig. 13, apertural view.
- Figs. 14 & 15, Saracenaria Z-7-56-G var. M, n.sp. X64. Fig. 14,  
side view, fig. 15, apertural view.
- Figs. 16 & 17, Saracenaria Z-7-56-G var. J, n.sp. X51. Fig. 16,  
side view, fig. 17, apertural view.
- Figs. 18 & 19, Saracenaria Z-7-54-L, n.sp. X52. Fig. 18,  
side view, fig. 19, apertural view.
- Figs. 20 & 21, Saracenaria? Z-7-56-C, n.sp. X84. Fig. 20,  
side view, fig. 21, apertural view.
- Figs. 22 & 23, Saracenaria Z-7-56-H, n.sp. X59. Fig. 22,  
side view, fig. 23, apertural view.



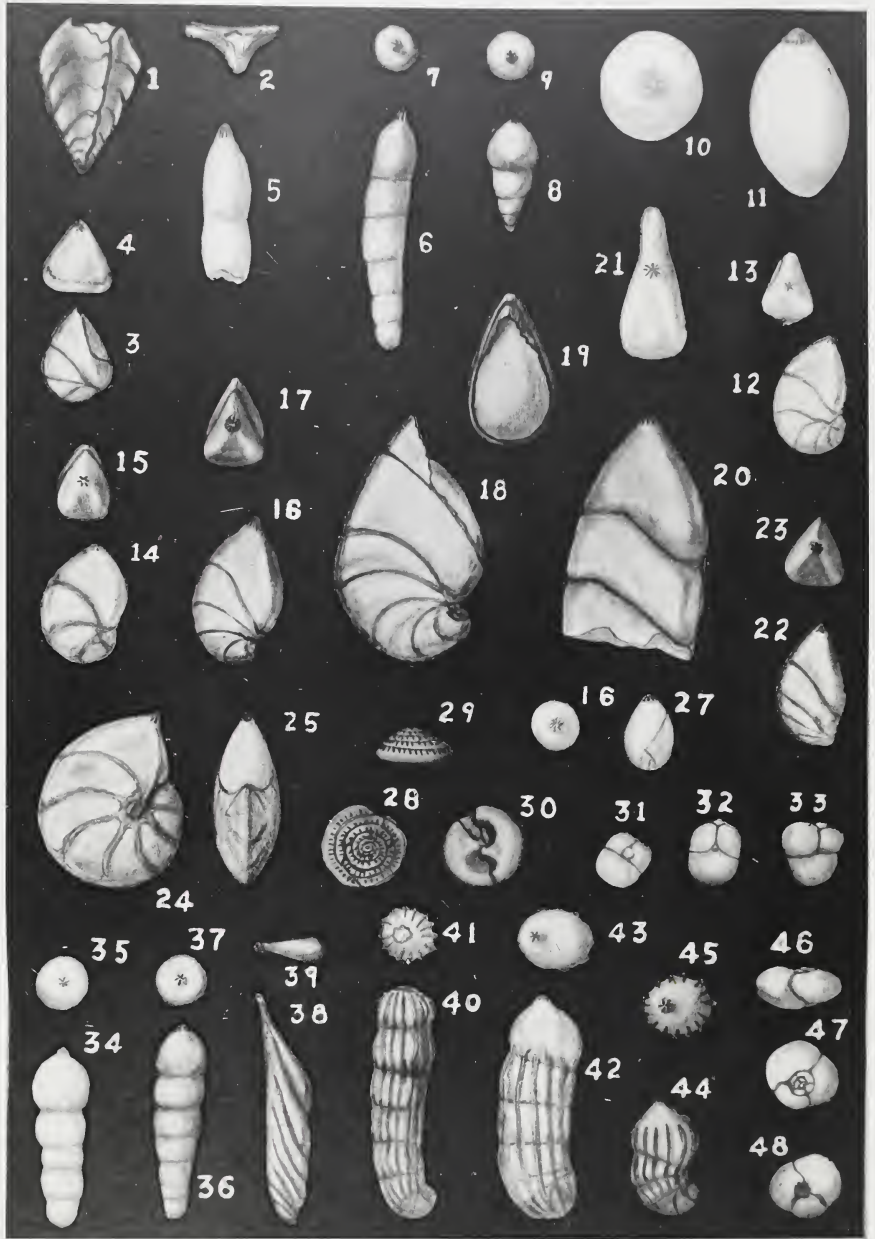


Plate II





## APPENDIX

### Location of Outcrops Sampled.

The shale samples collected by Mr. W.C. Bahan, which provide the material for this thesis, were taken from outcrops which make up the Clearwater formation type section and are exposed below Grand Rapids along the banks of the Athabaska river. The locations are shown on the accompanying map of the Athabaska river.

### Lithology of the Clearwater Formation

The following is an outline of the lithology of the Clearwater formation in the type section as described in the field by W.G. Bahan (Personal communication). The location in section of the microfaunal samples dealt with in this thesis are indicated by reference to sample number at appropriate horizons.

The section immediately following is a composite made from station to station with duplicated portions omitted as different marker beds were established down through the section. The composite section represents the total Clearwater shale from the base of the overlying Grand Rapids formation to the top of the underlying McMurray formation.



Station 1

Base of Grand Rapids formation

Top of Clearwater formation

- 13.0' Concealed.
- 0.8' Steel grey, crumbly, rubbly, sandy shale.
- 0.2' Light greenish-grey, fine-grained, glauconitic sand.
- 0.3' Orange brown weathered, grey to buff-grey ironstone, concretion.
- 1.0' Light greenish-grey, fine-grained kaolinitic (whitish specks) thin-bedded sand (beds up to 3" thick) alternating with thin ironstone concretions and very thin (less than 1") brownish-grey flaky, papery shale, some thin ( $\frac{1}{4}$ ") small lenses of coaly material.
- 6.0' Grey, weathering whitish-grey "pepper and salt", fine-grained massive, soft, sand with numerous irregular small lenses of dark grey clay or shale; occasional minute carbonaceous specks.
- 1.0' Light grey, fine-grained, calcareous sandstone band, thin bedded.
- 14.0' Dark grey, soft generally, silty, rubbly, shale with medium grey silt interbeds. Samples Z-2-5 and Z-2-W.L.
- 6.0' Dark grey, sandy shale and greenish-grey glauconitic fine sandstone alternations.
- 3.0' Greenish-grey, glauconitic, fine sand.
- 0.4' Carbonaceous ironstone concretion, slightly calcareous.
- 11.0' Glauconitic sand, as above, with dark grey shale interbeds; some rusty weathering ironstone bands local yellowish bentonitic clay material; locally the sand is very highly glauconitic and coarser, some bands of sand are brownish-grey, non-glauconitic; in lower part are huge (up to 3') yellowish weathered, light grey, calcareous sandstone concretionary bands - not continuous.



- 11.0' Light greenish-grey to light grey, fine-grained sand, silty, massive, very minor thin, brownish-grey, silty shale and silt breaks, laminated in bottom part.
- 11.5' Brownish-black to dark grey, silty, fractured shale and medium grey silt.
- 5.0' Dark grey to almost black, splintery, hackly, rectangular fractured, rubbly only slightly silty shale; more silty towards base.
- 6.0' Alternating light grey, laminated silty sand, silt and dark grey shale (in beds up to 4" thick) sand is glauconitic at base.
- 3.0' Greenish-grey to brownish-grey, fine massive sand.
- 0.4' Medium-grained grey calcareous concretionary sandstone.
- 12.0' Light grey to whitish grey kaolinitic sand with ironstone concretions with carbonaceous material; some very thin steel to dark grey, irregular shale breaks; sand is fairly resistant and somewhat cliff-forming. Samples Z-5 and Z-5-3.
- 8.0' Light grey, fine-grained, hard, thick bedded (up to 3' more or less) calcareous sandstone, contains some fossil wood and Pelecypods. "Nucula cancellata", weathers orange color locally; some calcareous, medium grey concretions, locally, paper thin dark grey shale between beds.
- 1.5' Medium-grey silt and dark grey silty shale, fractured.
- 1.0' Light grey, fine-grained calcareous sandstone with carbonaceous particles.
- 1.0' Grey to medium, soft, silty sand.

#### Station 2

- 2.5' Grey, hard, light brownish weathering, calcareous sandstone concretionary band.
- 3.0' Greenish-grey (to brownish-grey) fine, soft, sand with brownish weathering, thin ironstone band, thin dark grey to black flaky, soft shale lenses.





- 5.5' Light greenish-grey to whitish green, whitish speckled medium grained, glauconitic sand with thin interbeds of ironstone and brownish black shale; sand contains brownish laminations, thin black to brownish black coaly seams. Sample Z-7-8.
- 1.0' Dark grey sandy shale.
- 2.0' Sand, as above, mottled with irregular dark grey shale.
- 0.8' Whitish grey fine-grained, hard, calcareous sandstone concretions with carbonaceous particles.
- 7.5' Whitish grey, fine grained, kaolinitic massive, very light whitish weathering, sand with small irregular argillaceous inclusions; some small black carbonaceous particles.
- 0.2' Brownish weathering, sandy ironstone band.
- 1.0' Fine-grained, greenish grey sand.
- 2.0' Alternating dark brownish-grey crumbly silty shale and medium grey sand to silt. Sample Z-7-24.
- 0.8' Alternating hard grey silt and light grey calcareous sandstone, mottled with argillaceous material; little silty shale.
- 1.0' Light brownish-grey, calcareous, very fine-grained sandstone (almost a siltstone) concretionary band.
- 5.5' Alternating, fine-grained light greenish grey to grey sand, dark brown to dark grey shale, silty. Mostly concealed.
- 7.0' Dark grey, crumbly, silty shale and medium grey silt (to very fine silty sand).
- 9.5' Dark grey shale, as above, none or very minor silt breaks, sandy 1" concretionary band at base. Sample Z-7-48
- 5.5' Alternating dark grey, silty, splintery, shale and medium grey silt (varying to fine silty sand) in beds up to 1" more or less, and up to 4" thick. Sample Z-7-54
- 0.7' Grey, fine-grained, slightly calcareous sandstone.
- 2.4' Dark grey silty shale; silt to fine silty sand interbeds at base. Sample Z-7-56.



1. The first part of the book is devoted to a general survey of the history of the subject.	1
2. The second part is devoted to a detailed study of the various theories of the subject.	10
3. The third part is devoted to a critical examination of the various theories of the subject.	20
4. The fourth part is devoted to a study of the various methods of the subject.	30
5. The fifth part is devoted to a study of the various results of the subject.	40
6. The sixth part is devoted to a study of the various applications of the subject.	50
7. The seventh part is devoted to a study of the various problems of the subject.	60
8. The eighth part is devoted to a study of the various questions of the subject.	70
9. The ninth part is devoted to a study of the various theories of the subject.	80
10. The tenth part is devoted to a study of the various methods of the subject.	90
11. The eleventh part is devoted to a study of the various results of the subject.	100
12. The twelfth part is devoted to a study of the various applications of the subject.	110
13. The thirteenth part is devoted to a study of the various problems of the subject.	120
14. The fourteenth part is devoted to a study of the various questions of the subject.	130
15. The fifteenth part is devoted to a study of the various theories of the subject.	140
16. The sixteenth part is devoted to a study of the various methods of the subject.	150
17. The seventeenth part is devoted to a study of the various results of the subject.	160
18. The eighteenth part is devoted to a study of the various applications of the subject.	170
19. The nineteenth part is devoted to a study of the various problems of the subject.	180
20. The twentieth part is devoted to a study of the various questions of the subject.	190
21. The twenty-first part is devoted to a study of the various theories of the subject.	200
22. The twenty-second part is devoted to a study of the various methods of the subject.	210
23. The twenty-third part is devoted to a study of the various results of the subject.	220
24. The twenty-fourth part is devoted to a study of the various applications of the subject.	230
25. The twenty-fifth part is devoted to a study of the various problems of the subject.	240
26. The twenty-sixth part is devoted to a study of the various questions of the subject.	250
27. The twenty-seventh part is devoted to a study of the various theories of the subject.	260
28. The twenty-eighth part is devoted to a study of the various methods of the subject.	270
29. The twenty-ninth part is devoted to a study of the various results of the subject.	280
30. The thirtieth part is devoted to a study of the various applications of the subject.	290
31. The thirty-first part is devoted to a study of the various problems of the subject.	300
32. The thirty-second part is devoted to a study of the various questions of the subject.	310
33. The thirty-third part is devoted to a study of the various theories of the subject.	320
34. The thirty-fourth part is devoted to a study of the various methods of the subject.	330
35. The thirty-fifth part is devoted to a study of the various results of the subject.	340
36. The thirty-sixth part is devoted to a study of the various applications of the subject.	350
37. The thirty-seventh part is devoted to a study of the various problems of the subject.	360
38. The thirty-eighth part is devoted to a study of the various questions of the subject.	370
39. The thirty-ninth part is devoted to a study of the various theories of the subject.	380
40. The fortieth part is devoted to a study of the various methods of the subject.	390
41. The forty-first part is devoted to a study of the various results of the subject.	400
42. The forty-second part is devoted to a study of the various applications of the subject.	410
43. The forty-third part is devoted to a study of the various problems of the subject.	420
44. The forty-fourth part is devoted to a study of the various questions of the subject.	430
45. The forty-fifth part is devoted to a study of the various theories of the subject.	440
46. The forty-sixth part is devoted to a study of the various methods of the subject.	450
47. The forty-seventh part is devoted to a study of the various results of the subject.	460
48. The forty-eighth part is devoted to a study of the various applications of the subject.	470
49. The forty-ninth part is devoted to a study of the various problems of the subject.	480
50. The fiftieth part is devoted to a study of the various questions of the subject.	490

- 0.2' Medium to almost dark grey shaly siltstone band; contains minute black carbonaceous particles; irregular small patches of grey sand.
- 1.0' Grey laminated fine-grained, silty sand.
- 5.0' Rapidly very irregularly alternating dark grey silty shale (varying to silt) and medium to light brownish-grey silty fine sand; more shaly and darker towards base.
- 1.0' Medium grey silt; small irregular fine brownish-grey silty sand lenses.
- 1.0' Sandy to silty dark grey shale.
- 0.4' Medium-grey, cross laminated, fine silty sand.
- 6.0' Dark grey silty shale with very minor irregular lenses or breaks of silt and silty sand.
- 2.0' Alternating medium grey fine sandy silt (to silty sand) with thin interbeds of dark grey silty shale (silt in beds up to 4" thick) sand shows laminations.

### Station 3

- 7.0' Grey to greenish-grey chunky conchoidally fractured silt, varying to shaly and silty shale, conchoidally fractured, some rare black carbonaceous particles.
- 1.3' Dark grey splintery, rectangular fractured shale, varying to silty.
- 3.0' Silt as above, with irregular inclusions of dark grey shale; varying locally to silty sand.
- 2.5' Light to yellowish-grey, fine-grained, massive, somewhat consolidated silty laminated sand.
- 3.0' Shaly silt as above, varying to fine, shaly sand.
- 1.0' Light greenish-grey, laminated, fine sand.
- 2.3' Light to whitish-grey, hard, cross-bedded, very fine-grained calcareous sandstone.



- 3.0' Medium-grey, very hard, weathering yellowish-grey,  
very fine-grained sandstone, calcareous concretions;  
contains fossils.
- 4.0' Shaly silt as above.
- 30.0' Concealed.

Station 4

- 0.5' Dark grey flaky shale.
- 5.0' Dark brownish-grey, shaly bituminous sand.
- 21.0' Dark grey flaky shale - partly concealed.
- 5.0' Dark greenish-grey, shaly glauconitic sand.

Top McMurray formation.



## Statistical Analysis of Occurrence of Species

The following table shows the number of individuals of each species present in the portions of the microfaunal samples picked. Each species was completely picked except where otherwise indicated. This table is established to permit statistical comparison by future workers dealing with Clearwater equivalent suites.

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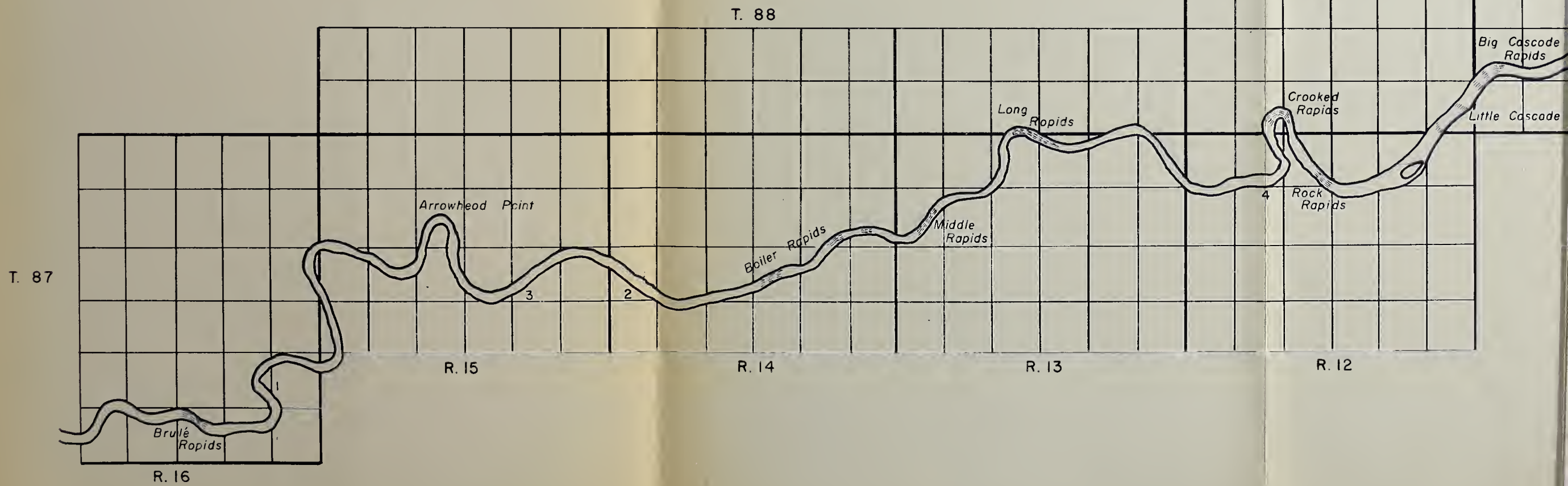
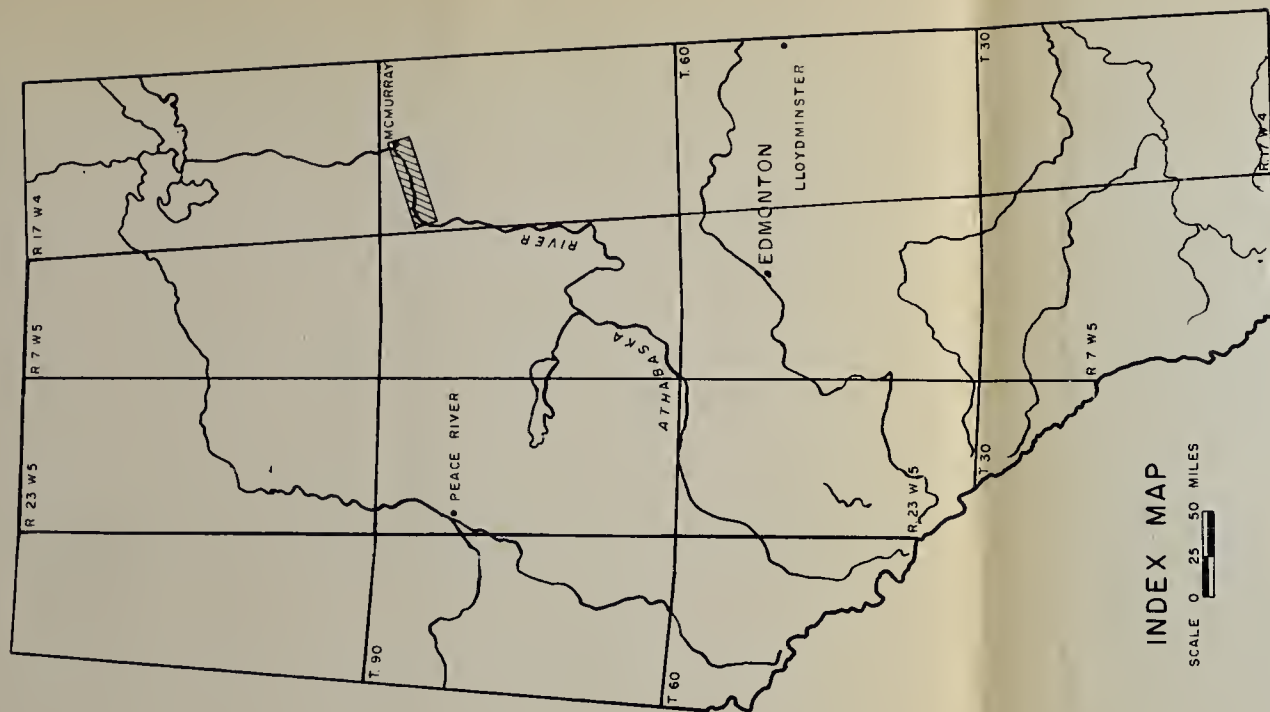
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Depth below top of Clearwater	24	29	95	98	125	161	181	187	189
Species	Z-2-5	Z-2-W.L.	Z-5	Z-5-3	Z-7-8	Z-7-24	Z-7-48	Z-7-54	Z-7-56
<u>Nodosaria</u> Z-7-54-A								1	
<u>Nodosaria</u> Z-7-48-C							1		
<u>Patellina</u> Z-7-56-A								3	12
<u>Saracenaria</u> Z-7-56-B							1		2
<u>Saracenaria</u> Z-7-56-C									2
<u>Saracenaria</u> Z-7-56-G var. A								2	3
<u>Saracenaria</u> Z-7-56-H								2	1
<u>Saracenaria</u> Z-7-56-G var. J								2	3
<u>Saracenaria</u> Z-7-54-L								1	
<u>Saracenaria</u> Z-7-56-G var. M								2	2
<u>Sphaeroidina</u> Z-7-54-A								1	
<u>Tristix</u> Z-7-54-A								2	
<u>Tritaxia</u> Z-5-A			8		8	1	2	51	104
<u>Vaginulina</u> Z-7-54-A								1	1
<u>Valvulineria</u> Z-7-54-C								2	3
<u>Verneuilina</u> Z-7-56-C	12		2	14	104	2	9	9	48
<u>Verneuilina</u> Z-7-56-D	5			2	16		14	15	96

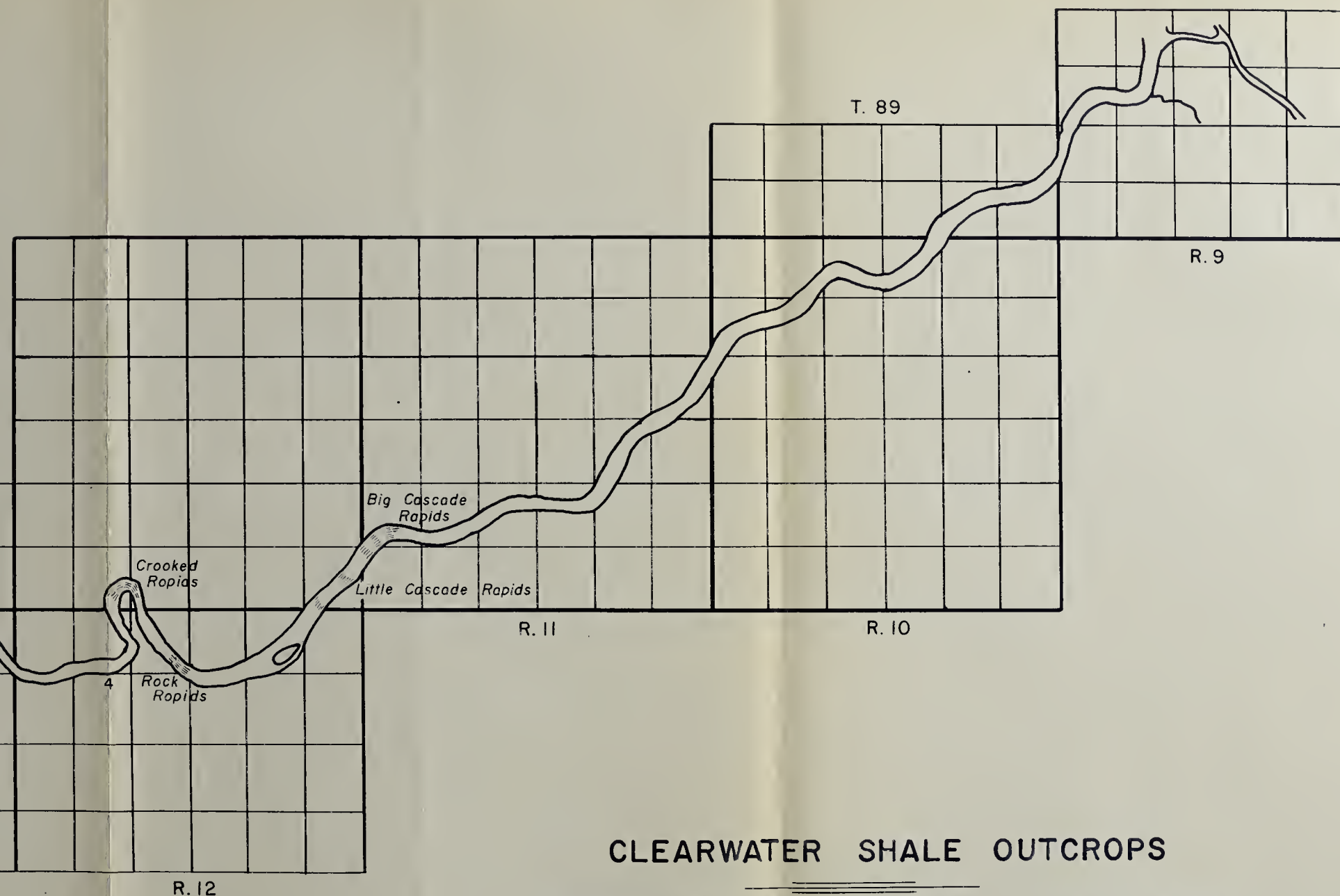
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CLEARWATER SHALE OUTCROPS

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ATHABASKA RIVER — ALBERTA

SCALE 0 1 2 MILES















**B29768**